

AMENDMENTS TO THE CLAIMS

1. (Original) A method of measuring at least one selected parameter at a location within a region of interest, which method comprises the steps of: launching optical pulses at a plurality of preselected interrogation wavelengths into an optical fibre deployed along the region of interest, reflectors being arrayed along the optical fibre to form an array of sensor elements, the optical path length between the said reflectors being dependent upon the selected parameter; detecting the returned optical interference signal for each of the preselected wavelengths; and determining from the optical interference signal the absolute optical path length between two reflectors at the said location, and from the optical path length so determined the value of the selected parameter at the said location.
2. (Original) A method as claimed in claim 1, wherein the step of determining the absolute optical path length comprises carrying out a process in which the derivative of the phase as a function of wavelength is estimated from a subset of the interference signals, using the derivative and an estimated value for the optical path length to estimate the phase relationship between the interference signals, and the phase relationship thus obtained is used to revise the estimated value for the optical path length, the process being repeated for increasing subsets of the remaining wavelengths in sequence, on the basis of the optical path length estimated for the immediately preceding subset in the sequence, thereby to progressively revise the optical path length until it is known to a desired level of accuracy.
3. (Canceled)
4. (Currently amended) A method as claimed in ~~any preceding~~ claim 1, wherein said optical fibre comprises polarisation-maintaining fibre and light is launched into the fibre in such a way that the power of the light signal is substantially equally divided between the orthogonally-polarised propagation modes of the fibre, thereby to interrogate each principal state of polarisation of the fibre simultaneously, the return interference signals from both principal states of polarisation being used separately in the said process for determining the absolute optical path length for each propagation mode independent of the other mode.
5. (Currently amended) A method as claimed in ~~any one of claims~~ claim 1 to 3, wherein the optical fibre comprises polarisation-maintaining fibre and light is launched into

the fibre in such a way that the power of the light signal is firstly directed entirely into one of the principal states of polarisation and then the other, thereby to interrogate the principal states of polarisation sequentially, the returned interference signals from both principal states of polarisation being used separately in the said process for determining the absolute optical path length for each propagation mode independent of the other mode.

6. (Currently amended) A method as claimed in ~~any one of claims~~ claim 1 to 5, in which the selected parameter comprises temperature.

7. (Canceled)

8. (Canceled)

9. (Canceled)

10. (Currently amended) A method as claimed in ~~any one of claims~~ claim 1 to 5, in which the selected parameter comprises strain.

11. (Original) A method as claimed in claim 10, wherein the optical fibre is a high-birefringence fibre, the birefringence of which changes in response to strain applied to the optical fibre.

12. (Original) A method as claimed in claim 11, wherein the birefringence of the high-birefringence fibre also changes in response to temperature, and the method further comprises compensating the returned optical interference signal for effects arising from temperature at the said location.

13. (Canceled)

14. (Currently amended) A method as claimed in ~~any one of claims~~ claim 1 to 5, in which the selected parameter comprises pressure.

15. (Original) A method as claimed in claim 14, wherein the said optical fibre comprises a side-hole fibre.

16. (Original) A method as claimed in claim 15, wherein each sensor element of the fibre is located within a sealed elliptical tube filled with a pressure-transmitting fluid.

17. (Canceled)

18. (Canceled)

19. (Currently amended) A method as claimed in ~~any one of claims~~ claim 1 to 5, wherein the selected parameter depends on a localised event moving along the region of interest, and the method comprises determining the value of the selected parameter over time at more than one said location, and determining the movement of the localised event from the determined values of the selected parameter.

20. (Original) A method as claimed in claim 19, wherein the localised event is a user-induced event, and the method further comprises inducing the localised event.

21. (Currently amended) A method as claimed in claim 19 ~~or claim 20~~, wherein the localised event is a volume of fluid within the region of interest that has a different temperature, pressure, or density from surrounding fluid in the region of interest, the selected parameter being temperature, pressure, or density, respectively.

22. (Currently amended) A method as claimed in ~~any preceding~~ claim 1, wherein at least two selected parameters are measured simultaneously.

23. (Canceled)

24. (Canceled)

25. (Canceled)

26. (Currently amended) A method as claimed in ~~any preceding~~ claim 1, wherein the measured value for the parameter is used to determine the value for a further measurand

dependent upon the said parameter and wherein the said optical fibre is provided with a coating which responds to the said further measurand by stretching or shrinking.

27. (Canceled)

28. (Currently amended) A method as claimed in claim 26 27, wherein the said coating is electro-strictive.

29. (Currently amended) A method as claimed in claim 26 27, wherein the said coating is magneto-strictive.

30. (Currently amended) A method as claimed in claim 26 27, wherein the said coating is sensitive to a selected chemical measurand.

31. (Canceled)

32. (Canceled)

33. (Canceled)

34. (Canceled)

35. (Currently amended) A method as claimed in ~~any preceding~~ claim 1, wherein the returned optical interference signal is processed to remove the cross-talk term, the cross-talk term being removed for each of n sensor elements by subtracting the cross-talk phasor for the nth sensor element from the measured nth sensor element phasor, the removal process beginning with subtraction of the cross-talk phasor for the second sensor element from the measured second sensor element phasor, the cross-talk phasor for the first sensor element in the array being zero.

36. (Currently amended) A method according to ~~any preceding~~ claim 1, wherein the region of interest lies within an oil well.

37. (Canceled)

38. (Canceled)

39. (Original) Apparatus for measuring a selected physical parameter at a location within a region of interest, which apparatus comprises: an optical fibre for deployment along the region of interest, the optical fibre having reflectors therealong forming an array of sensor elements, the optical path length between the said reflectors being dependent upon the selected parameter; source means operable to launch optical pulses at a plurality of preselected interrogation wavelengths into the said fibre; signal detection means operable to detect the returned optical interference signal for each of the preselected wavelengths; and signal processing means operable to determine from the optical interference signal the absolute optical path length between two reflectors at the said location and to determine from the optical path length so determined the value of the selected parameter at the said location.

40. (Original) Apparatus as claimed in claim 39, wherein the said signal processing means is operable to determine the absolute optical path length by carrying out a process in which the derivative of the phase as a function of wavelength is estimated from a subset of the interference signals, using the derivative and an estimated value for the optical path length to estimate the phase relationship between the interference signals, and the phase relationship thus obtained is used to revise the estimated value for the optical path length, the process being repeated for increasing subsets of the remaining wavelengths in sequence, on the basis of the optical path length estimated for the immediately preceding subset in the sequence, thereby to progressively revise the optical path length until it is known to a desired level of accuracy.

41. (Canceled)

42. (Currently amended) Apparatus as claimed in ~~any one of claims~~ claim 39 to 41, wherein the said optical fibre comprises polarisation-maintaining fibre, and the apparatus further comprises power launching means operable to launch the optical pulses into the fibre in such a way that the power of the optical pulses is substantially divided between the orthogonally-polarised propagation modes of the fibre, thereby to interrogate each principal state of polarisation of the fibre simultaneously; and the signal processing means being

operable to use the returned optical interference signals from both principal states of polarisation separately to determine the absolute optical path length for each propagation mode independent of the other mode.

43. (Currently amended) Apparatus as claimed in ~~any one of claims~~ claim 39 to 41, wherein the said optical fibre comprises polarisation-maintaining fibre, and the apparatus further comprises a polarisation modulator operable to launch the optical pulses into the fibre in such a way that the power of the optical pulses is firstly directed entirely into one of the principal states of polarisation of the fibre and then the other, thereby to interrogate the principal states of polarisation sequentially; and the signal processing means being operable to use the returned optical interference signals from both principal states of polarisation separately to determine the absolute optical path length for each propagation mode independent of the other mode.

44. (Currently amended) Apparatus as claimed in ~~any one of claims~~ claim 39 to 43, wherein the parameter comprises temperature.

45. (Canceled)

46. (Canceled)

47. (Canceled)

48. (Currently amended) Apparatus as claimed in ~~any one of claims~~ claim 39 to 43, wherein the parameter comprises strain.

49. (Original) Apparatus as claimed in claim 48, wherein the optical fibre is a high-birefringence fibre, the birefringence of which changes in response to strain applied to the optical fibre.

50. (Original) Apparatus as claimed in claim 49, wherein the birefringence of the high birefringence fibre also changes in response to temperature, and the signal processing means is further operable to compensate the returned optical interference signal for effects arising from temperature at the said location.

51. (Canceled)

52. (Currently amended) Apparatus as claimed in ~~any one of claims~~ claim 39 to 43, wherein the parameter comprises pressure.

53. (Original) Apparatus as claimed in claim 52, wherein the said optical fibre comprises a side-hole fibre.

54. (Original) Apparatus as claimed in claim 53, wherein each sensor element of the fibre is located within a sealed elliptical tube filled with a pressure-transmitting fluid.

55. (Canceled)

56. (Canceled)

57. (Currently amended) Apparatus according to ~~any one of claims~~ claim 39 to 43, wherein the selected parameter depends on a localised event moving along the region of interest, and the signal processing means is operable to determine the value of the selected parameter over time at more than one said location, and to determine the movement of the localised event from the determined values of the selected parameter.

58. (Original) Apparatus according to claim 57, wherein the localised event is a user-induced event.

59. (Original) Apparatus according to claim 58, wherein the localised event is a volume of fluid within the region of interest that has a different temperature, pressure, or density from surrounding fluid in the region of interest, the selected parameter being temperature, pressure, or density, respectively.

60. (Currently amended) Apparatus as claimed in ~~any one of claims~~ claim 39 to 59, and further for measuring a second selected physical parameter at the location within the region of interest, wherein said optical path length between the said reflectors is further dependent upon the second selected parameter; and the signal processing means is further operable to

determine the value of the second selected physical parameter from the determined absolute optical path length.

61. (Canceled)

62. (Canceled)

63. (Canceled)

64. (Currently amended) Apparatus as claimed in ~~any one of claims claim~~ claim 61 to 63, operable to use the measured value for the parameter to determine a value for a further measurand dependent upon said parameter, and wherein the said optical fibre is provided with a coating which responds to the said further measurand by stretching or shrinking.

65. (Canceled)

66. (Currently amended) Apparatus as claimed in claim 64 65, wherein the said coating is electro-strictive.

67. (Currently amended) Apparatus as claimed in claim 64 65, wherein the said coating is magneto-strictive.

68. (Currently amended) Apparatus as claimed in claim 64 65, wherein the coating is designed to be sensitive to a selected chemical measurand.

69. (Currently amended) Apparatus as claimed in ~~any one of claims claim~~ claim 39 to 68, wherein the source means are operable to launch light at a fixed wavelength and at a varying wavelength into the fibre, and the signal processing means are operable to use the interference signal from interrogation at the fixed wavelength to determine high frequency phase changes.

70. (Original) Apparatus as claimed in claim 69, further comprising an auxiliary optical fibre for deployment through the region of interest, reflectors being arrayed along the fibre

to form an auxiliary array of sensor elements, the source means being operable to launch the fixed wavelength signal into the auxiliary fibre.

71. (Original) Apparatus as claimed in claim 70, where the auxiliary fibre has a coating designed to enhance acoustic sensitivity.

72. (Currently amended) Apparatus as claimed in ~~any one of claims~~ claim 69 ~~to 71~~, wherein the signal processing means are further operable to use the high frequency phase changes to correct for dynamic errors in the returned optical interference signals.

73. (Currently amended) Apparatus as claimed in ~~any of claims~~ claim 39 ~~to 72~~, wherein the signal processing means is further operable to process the returned optical interference signal to remove the cross-talk term, the cross-talk term being removed for each of the n sensor elements by subtracting the cross-talk phasor for the n th sensor element from the measured n th sensor element phasor, the removal process beginning with subtraction of the cross-talk phasor for the second sensor element from the measured second sensor element phasor, the cross-talk phasor for the first sensor element in the array being zero.

74. (Currently amended) Apparatus according to ~~any one of claims~~ claim 39 ~~to 73~~, wherein the region of interest lies within an oil well.

75. (Canceled)

76. (Canceled)

77. (Original) A method of measuring a parameter in an optical fibre interferometric array, comprising launching optical pulses into the array, creating an interference signal within sensor elements in the array, detecting the phase of the interference signals, wherein the returned optical interference signal is processed to remove the cross-talk term, the cross-talk term being removed for each of n sensor elements by subtracting the cross-talk phasor for the n th sensor element from the measured n th sensor element phasor, the removal process beginning with subtraction of the cross-talk phasor for the second sensor element from the measured second sensor element phasor, the cross-talk phasor for the first sensor element in the array being zero.